Biological Invasions (2006) 8: 787–795
DOI: 10.1007/s10530-005-3837-6

Barging in: a temperate marine community travels to the subantarctic

Patrick N. Lewis[1,*], Dana M. Bergstrom[2] & Jennie Whinam[3]
[1]*Institute of Antarctic and Southern Ocean Studies, University of Tasmania, Private Bag 77, Hobart, 7001, Australia;* [2]*Australian Antarctic Division, Channel Highway, Kingston, 7050, Australia;* [3]*Department of Primary Industry, Water and Environment, Nature Conservation Branch, GPO Box 44, Hobart, 7001, Australia; *Author for correspondence (e-mail: plewis@utas.edu.au; fax: +61-3-62262973)*

Received 5 December 2004; accepted in revised form 16 March 2005

Key words: fouling, invasive, Macquarie Island, marine, non-indigenous, quarantine, subantarctic

Abstract

A diverse fouling community discovered encrusting a barge intended for deployment at subantarctic Macquarie Island is described and its role as a transport vector for non-indigenous marine organisms is discussed. The barge proved to be a potential vector capable of transporting entire epi-bethic communities, 20 species in total, from a temperate estuarine system (Derwent River, Tasmania, Australia) into the subantarctic. For one invasive amphipod species *Monocorophium acherusicum*, over 136000 individuals including ovigerous females were calculated to be associated with the barge fouling community. Although distinct differences exist between the thermal ranges of Macquarie Island and the Bruny bioregion of Tasmania, a hazard assessment based on the Gower similarity coefficient suggested sufficient similarity between the two environments to allow for survival of transported organisms for eight months of the year. Several invasive species are able to survive the thermal conditions of the subantarctic irrespective of the time of year. This study identifies the need for effective quarantine measures aimed at identifying and managing marine biosecurity hazards in association with human activities in high latitude regions.

Introduction

The establishment of invasive organisms in the subantarctic islands is recognized as one of the foremost threats to native communities in this region (Lewis et al. 2003, 2005a,b; Frenot et al. 2005). Quarantine measures are relied on to limit the influx of biological material from temperate regions into subantarctic and Antarctic environments (Frenot et al. in press; Whinam et al. 2005), and also to prevent the transfer of pathogens and material between islands and regions (Kerry et al. 1999). Over the last decade stringent codes of quarantine have been developed by many national operators in the Southern Ocean, however procedures are generally aimed at controlling the movement of terrestrial material such as seeds and invertebrates in association with expeditioners, equipment and food. Little consideration as yet has been provided towards marine biosecurity and the transport of exogenous aquatic organisms associated with materials intended for deployment in the marine environment.

Currently identified transport pathways for marine introductions such as vessel traffic (Lewis et al. 2003, 2005a,b) and plastic debris (Barnes 2002; Barnes and Fraser 2003; Barnes and Milner 2005) offer little opportunity for the instigation of voyage specific quarantine measures and require a re-appraisal of general shipping operations and a greater awareness of the impacts associated with marine pollution. In contrast, science and re-supply operations in the subantarctic islands frequently introduce small vessels, ropes, barges, scientific equipment and other material into the marine environment. These objects, which are stored aboard the larger re-supply vessels during transit, offer ample opportunity for screening for potential exogenous organisms and the application of standardised cleaning protocols.

Here we report the discovery of an intact and viable marine community, including several invasive organisms, fouling a barge intended for deployment at the subantarctic Macquarie Island (Figure 1). Although prompt action by science personnel identified the biological hazard associated with this community (Whinam et al. 2005), and operation personnel immediately took action to reduce the risk (including steam cleaning and the non-deployment of the barge), the discovery was largely a matter of serendipity and demonstrates the need for constant vigilance and formal quarantine guidelines. An analysis of the composition of the community and associated risks indicates the existence of a viable transport pathway. We conclude that a basic awareness of simple quarantine precautions must be applied to such objects to ensure that they do not carry entrained biological assemblages into subantarctic environments.

Methods

The presence of a biosecurity hazard in the form of a barge heavily fouled with marine biota was noted during an investigation of potential pathways and vector platforms for non-indigenous biota associated with an Australian Antarctic Program expedition to Macquarie Island (54°30′ S, 158°57′ E) (Whinam et al. 2005). Table 1 shows the history of the barge, which was exposed to settlement by marine biota in the Derwent River (Hobart, Tasmania) for longer than one month prior to loading aboard the research and supply vessel *RSV Aurora Australis* on Voyage 8 bound for Macquarie Island. The barge was intended to be used to retrieve heavy equipment from the shore to the supply vessel.

Collection

The barge was inspected on Monday 11th March, 2002. Following the identification of the barge as a hazard all accessible surfaces were scraped of encrusting biota. The material collected from the barge was immediately frozen and retained for identification and enumeration. As investigators could not reach further than 60 cm under the barge, a portion of the under-

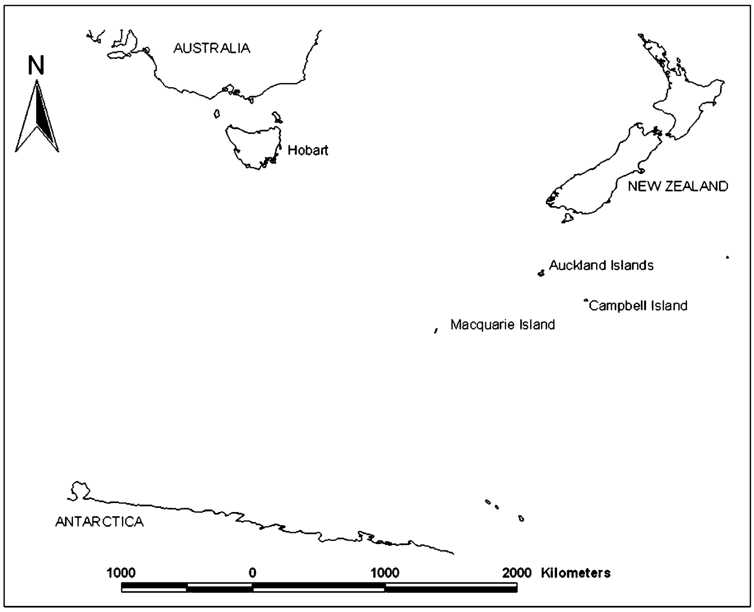

Figure 1. Location of Macquarie Island which lies approximately 1540 km south–east of Tasmania.

Table 1. The time sequence of the barge intended for deployment at Macquarie Island.

Date	Activity	Temp	Time of emersion (h)
23–26.01.2002	Barge introduced to the Derwent River	–	–
09.03.2002	Barge loaded: ~17:00 h	–	0
10.03.2002	V8 Departs: 17:05 h	–	24.05
11.03.2002	Barge inspected: 09:00 h	12.5	40
	Barge Steam-cleaned: 16:00 h	–	47
12.03.2002	Voyage report: 16:00 h	11.4	71
13.03.2002	V8 Arrives at Macquarie Island: 07:30 h	7.9	85.30 (theoretical)

Information was extracted from the situation reports of the *RV Aurora Australis*.

side could not be cleaned. At 4:00 pm on the same day, the barge was exposed to a steam spray to further reduce the hazard and a management decision was made not to deploy the barge at Macquarie Island.

Identification

The material collected from the barge was floated in fresh water, homogenised and separated into thirds (33.3%). Each third was divided into quarters (8.3%) and again into quarters (2.1%). Half (1.05%) of two 2.1% sub-samples was retained from each third to provide a total of six ~1% sub-samples. Each sub-sample was fractioned into three classes: 0.5, 1 and 2 mm. Samples were identified using a dissecting microscope and dominant species were counted in a Bogorov sorting tray to provide an extrapolation of the total population associated with the barge.

Hazard assessment

A basic hazard assessment was conducted according to the protocol set out in Hays and Hewitt (2000a). This approach compares the thermal similarity between donor and recipient regions and uses this similarity as a proxy for the hazard of biological transfer between regions. The Gower Similarity Coefficient (Gower 1971) was used to gain a similarity measure based upon the maximum and minimum water temperatures from each month. The similarity coefficient compares a characteristic 'k' (monthly thermal extremes) of two entities i and j, and allocates a score s_{ijk}, which is zero when i and j are completely different, a positive fraction when there is some degree of similarity, and unity when i and j are identical (Hays and Hewitt 2000a). For the purpose of this assessment a similarity measure of > 0.5 is considered significant. This approach calculates the similarity as follows:

$$S_{ij} = \sum_{k=1}^{n} s_{ijk} \Bigg/ \sum_{k=1}^{n} \delta_{ijk}$$

where $\delta_{ijk} = 1$ when character k can be compared for i and j, and zero when it cannot due to missing data.

Results

At the time of initial inspection of the barge, it had been out of the water for at least 40 h (Table 1). Three species of green algae and one species of red algae formed a substantial habitat matrix upon the sides and hull of the barge. Within this algal habitat the presence of numerous live crustaceans (amphipods and crabs), starfish (*Pateriella regularis*), and mussels (*Mytilus galloprovincialis*) were observed. Underneath the barge an extensive surface encrusted by barnacles (*Elminius modestus*) was estimated to include millions of individuals. Many of the barnacles were dead, or showed signs of severe dehydration.

Table 2 shows the species identified from samples collected from the Macquarie Island barge. Of the 20 species recorded, eight species are considered as invasive within Australia, and a further two species that are native to Australia have established invasive populations in other regions. Many ovigerous individuals of the brooding amphipods *Caprella acanthopgaster*, *Monocorophium acherusicum* and *Jassa marmorata* were sampled. Likewise, mature ovicells were present on the bryozoan *Tricellaria occidentalis* and gonotheca were present upon the hydroid *Obelia dichotoma*.

Table 2. Species identified from the fouling community attached to the barge.

Taxon group	Species	Native distribution	References
Algae	*Ulva rigida* (Sea lettuce)	Cosmopolitan	
	Enteromorpha intestinalis (Green algae)	Cosmopolitan	
	Cladophorpha sp. (Green algae)	N/A	
	Rodophyta sp. (Reg algae)	N/A	
Crustacea	*Elminius modestus*§ (Barnacle)	Australia (introduced to UK)	Crisp (1968)
	Zeuxo sp. (tanaid)	N/A	
	*Petrolisthes elongates** (New Zealand half-crab)	New Zealand	Aquenal (2002)
	*Jassa marmorata** (amphipod)	Atlantic, North Pacific	Poore and Storey (1999)
	*Monocorophium acherusicum** (amphipod)	Europe	Poore and Storey (1999)
	*Caprella acanthogaster** (amphipod)	North Hemisphere	Guerra-Garcia and Takeuchi (2004)
	Caprella penantis (amphipod)	Cosmopolitan	
	Paridotea ungulate (isopod)	Cosmopolitan, New Zealand Southern Islands	
	Fa. Sphaeromatidae (isopod)	N/A	
Bryozoa	*Watersiporia subtorquata** (Encrusting bryozoan)	North Hemisphere (introduced to Australia, New Zealand)	Keough and Ross (1999)
	*Tricellaria occidentalis** (Erect bryozoan)	North Hemisphere (introduced to Australia, New Zealand)	Keough and Ross (1999)
Hydroids	*Obelia dichotoma** (Hydroid)	Cosmopolitan (introduced to Australia)	Watson (1999)
Ascidian	*Asterocarpa humilis* (Ascidian)	South Hemisphere, East Pacific	
Mollusca	*Mytilus galloprovincialis*§ (Mussel)	Cosmopolitan (introduced to South Africa)	Stewart Grant and Cherry (1985)
Echinodermata	*Pateriella regularis** (Cushion star)	New Zealand	Aquenal (2002)
Insecta	Fa. Chironomidae (Midge larvae)	N/A	

Species that are known to be introduced to Australian waters are marked (*) and species that are native to Australia but non-indigenous elsewhere in the world are marked (§). References documenting the invasive history of the species are provided.

Due to the fractured state of sessile organisms such as hydroids and barnacles, reliable quantification of populations was restricted to mobile organisms. Three species of amphipod known to be non-indigenous in Australian waters were counted in each of the sub-samples (Table 3). Extrapolations estimating the number of individuals collected from the 60 cm band scraped from the barge yielded a population estimate of 136000 individuals for *Monocorophium acherusicum*, 3270 individuals of *Jassa marmorata* and 3910 individuals of *C. acanthogaster*.

Discussion

Our findings highlight an important and often overlooked component of Southern Ocean quarantine procedures. Clearly, any object immersed in the marine environment for a significant period will accumulate a community of sessile epi-benthic invertebrates which will provide a habitat matrix for various motile organisms. The fouling community recorded on the barge colonised and established over a one month period in a temperate estuarine system. Included in this assemblage were several invasive species that have displaced native species, including some endemics, in temperate waters. The main question – would it have been possible for the species from the barge to establish in a subantarctic coastal environment? – is explored below.

The biological, chemical and physical environment of a potential recipient region will directly affect the ability of an introduced organism to establish a population in the new habitat. Although attempts to predict the invasiveness of an organism based upon such attributes have generally provided only marginally useful information, a few key traits have been used to predict the potential for a species to survive the process of up-

Table 3. The numbers of three species of non-indigenous amphipod recorded in the sub-samples taken from the barge census.

		Monocorophium acherusicum		*Jassa Marmorata*		*Caprella acanthogaster*	
		n	*x*	*n*	*x*	*n*	*x*
500 μm fraction	1	387	418.3	1	0.5	3	2.8
	2	419		0		4	
	3	471		0		1	
	4	407		0		6	
	5	423		0		2	
	6	403		2		1	
1 mm fraction	1	578	598.7	8	4.2	3	8
	2	619		2		8	
	3	605		4		6	
	4	623		3		10	
	5	591		5		9	
	6	576		3		12	
2 mm fraction	1	350	349	28	28	26	28.3
	2	357		22		31	
	3	294		34		23	
	4	347		27		21	
	5	398		30		37	
	6	348		27		32	
N			136600		3270		3910

Numbers of individuals recorded in each sub-sample (*n*), the mean number of individuals (*x*) and the estimated total population of the barge (*N*) are provided for each size-based fraction

take, transport and establishment associated with human-mediated marine introductions (Hays and Hewitt 2000a). Prolonged emersion of the barge would have been a key parameter affecting survival during the four-day transit time. Sea temperature would have also effected survival in the event that live organisms were introduced to the littoral Macquarie Island environment.

Emersion response

Species able to survive in inter-tidal habitats are more likely to survive prolonged periods of emersion due the periodic exposure to the aerial environment associated with their habitat (Coleman 1973; Kennedy 1976; Davenport and Irwin 2003; Greenaway 2003). Littoral mussels capable of retaining fluids within their mantle cavity to prevent desiccation can survive for days out of the marine environment, and *Mytilus edulis* has been shown capable of surviving emersion for periods as long as 200 h (Kennedy 1976). It seems likely that the *Mytilus galloprovincialis* observed on the barge would have been able to survive the ~85 h journey to Macquarie Island.

Barnacles are particularly well adapted to survive emersion due to their ability to undertake aerobic respiration whilst guarding against desiccation through the alternative opening and closing of their valves (Barnes and Barnes 1957; Barnes et al. 1963; Davenport and Irwin 2003). For example, the inter-tidal species *Jehlius cirratus* can survive emersion (LP100) for up 75 days (LP50 = 25 days) (Castro et al. 2001). While no experimental data for *E. modestus* was found to demonstrate comparable lethal periods of exposure, this species has been shown to survive prolonged periods (>20 h) in circumstances where the mantle cavity is entirely filled by air (Davenport and Irwin 2003).

The observation of live New Zealand porcelain crabs (*Petrolisthes elongates*) amidst the fouling demonstrates that the environmental conditions within the matrix of macrophyte fouling can provide micro-environments capable of supporting species sensitive to desiccation. Jones and Greenwood (1998) showed that *Petrolisthes elongates* was vulnerable to dehydration during emersion, and demonstrated that a lethal body-water loss of 20.8% would occur in large crabs within 26 h of exposure, and that lethal exposure periods were

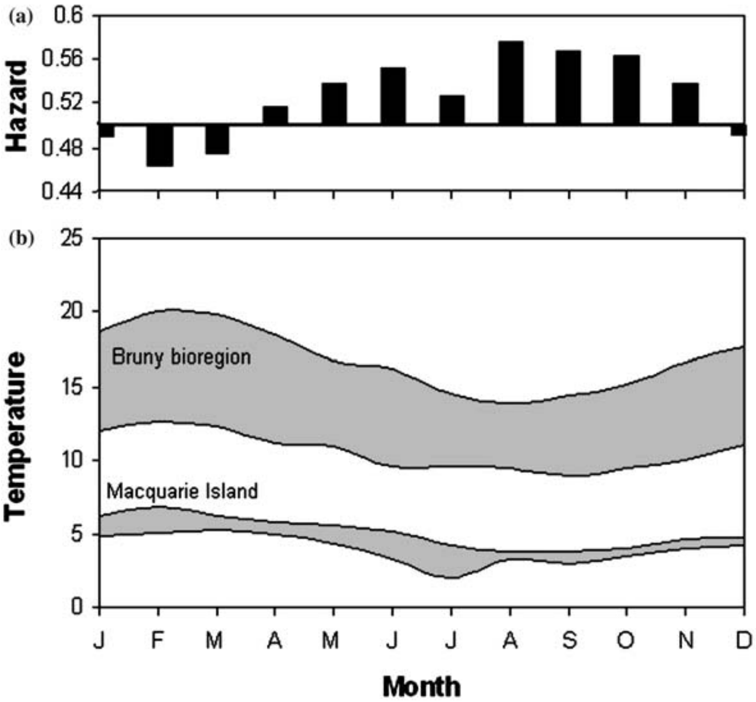

Figure 2. (a) Hazard assessment based upon the thermal similarity of the Bruny bio-regions Tasmania and Macquarie Island. The hazard rating was calculated using the Gower Similarity coefficient (Gower 1971) based upon the monthly maximum and minimum temperatures. (b) Thermal ranges of the Bruny Bioregion and Macquarie Island. Bruny thermal data was provided by the Centre for Research on Marine Introduced Species (CRIMP). Macquarie Island thermal data was provided by the National Tidal Facility (NTF).

shorter in smaller individuals. The observation of live crabs capable of unimpaired movement on the barge after 40 h of emersion would indicate that the humid micro-environments within the dense canopy of *Ulva rigida* are capable of providing refugia to more vulnerable species. Such micro-habitats have previously been shown to support sensitive assemblages during trials of emersion as a control measure for non-indigenous species (Garnham 1998; McEnnulty et al. 2001). The barge was secured to the front deck of the *Aurora Australis* and would have been exposed to humid sea air as well as wave splash, factors which may have contributed to the maintenance of an amenable micro-environment during transport.

While the exposure to the atmosphere for a period of 84 h clearly represents a stress to individuals entrained upon the barge, such a stress may trigger spawning or the release of propagules and thus increase the potential for a release of individuals into subantarctic environments. The barnacle *E. modestus* has been shown to respond to periods of prolonged emersion by closing the opercular valve and storing larvae which are released in large quantities upon re-immersion (Cawthorne and Davenport 1980). Likewise, stress often induces spawning in mytilid mussels, and stress-induced larval release by *Mytilus galloprovincials* has been observed to enable liberated larvae to successfully settle on surfaces even in environments that are clearly causing stress in the mature individuals (Apte et al. 2000).

Thermal similarity

The thermal similarities of two regions have previously been employed as a measure of risk for marine introductions through an environment-matching approach (Hilliard and Raaymakers 1997). A comparison of the thermal regime of the Bruny bioregion (southern Tasmania) (the donor environment) and Macquarie Island (the recipient environment) is provided in Figure 2b. A simple hazard assessment (following Hayes and Hewitt, 2000a,b) was used to determine the potential for species from the Hobart biogeographic region to survive transfer to Macquarie Island. Figure 2a shows the result of the hazard assessment and indicates a significant similarity (>0.5) between the regions for the eight months of the year (April–November). The four summer months when similarities between Tasmanian and Macquarie Island are below 0.5 (including March when the barge was destined for the island), however, may be sufficient to prevent the establishment of temperate species, particularly when this period coincides with the peak reproductive period of potentially invasive organisms.

The results of the hazard assessment should be treated with some degree of caution and the use of thermal comparisons to denote bio-security hazards have been criticised because most species have thermal tolerances that extend well beyond the extremes recorded in their environment (Hewitt and Hays 2002). Species-specific risk assessments are generally advocated as a more conservative approach (Hays and Hewitt 1998, 2000a,b, 2002). While little data is available regarding the thermal tolerance of the species recorded in this study, an examination of some well known invasive species indicates that several invasive organisms established in Tasmanian coastal waters are capable of

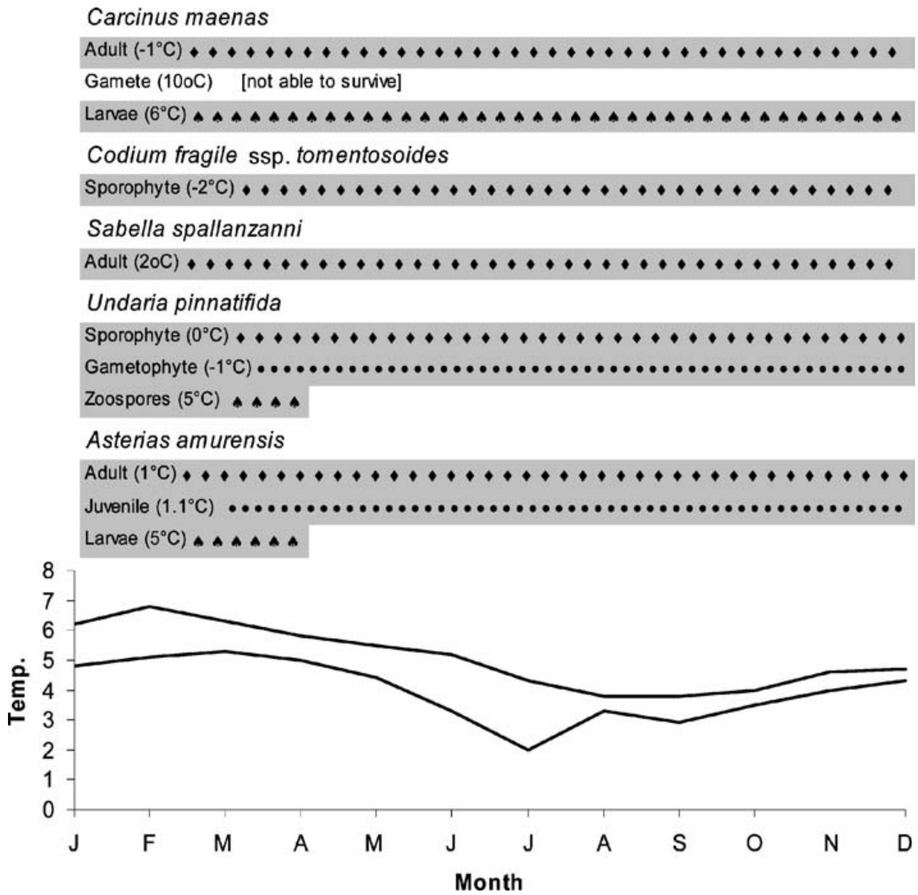

Figure 3. The lower thermal tolerances of five species of invasive marine pests established in Tasmanian coastal waters compared with the thermal range of Macquarie Island coastal waters. Lower thermal tolerances are provided in parenthesis, and the ability to survive in Macquarie Island is demonstrated by the band of symbols corresponding to survival during each month. While larval tolerances of *Carcinus maenas* precludes this species from establishing in Macquarie Island, other species are able to complete their life-cycle and are considered as high-risk species. Thermal tolerance data was provided by the Centre for Research on Introduced Marine Pests (CRIMP). Thermal data was provided by the National Tidal Facility (NTF).

surviving in the temperatures typical of Macquarie Island (Figure 3). Despite no overlap occurring in the thermal regime of the two environments (Figure 2), it is clear that many invasive species are able to survive in both regions and it is likely that other species such as those entrained upon the barge could also establish in the coastal waters of Macquarie Island.

Concluding remarks

The observation of a viable marine assemblage entrained on an object intended for deployment at Macquarie Island highlights just one of the many mechanisms by which non-indigenous marine organisms can be introduced to the subantarctic islands. Since the recognition of the pathway, the Australian Antarctic Division has introduced barge cleaning procedures consisting of obligatory emersion periods and high-pressure cleaning prior to loading of marine equipment, with particular attention paid to the cleaning of water inlets and immersed surfaces. The Australian Antarctic Division adaptive management strategy has also incorporated an awareness of biosecurity in the quarantine education program for expeditioners. Such education of expeditioners and logistics officers and the introduction of formal guidelines can reduce the biosecurity hazard associated with material that may be immersed in marine and freshwater environments in the subantarctic.

Acknowledgements

This project was supported by the Australian Antarctic Program, the Australian Antarctic Division and the Tasmanian Resource Management and Conservation Division. We appreciate the openness in which the Operations Branch of the Australian Antarctic Division allowed scientific scrutiny of their logistic activities. We gratefully acknowledge the assistance provided by Geof Copson and Nicki Chilcott in scraping and collecting organisms from the barge. We thank the National Tidal Facility for the provision of temperature data and Susan Stallman for her support as Voyage Leader. We acknowledge the support and the decisive actions of Geoff Dannock that resulted in the non-deployment of the barge at Macquarie Island.

References

Apte S, Holland BS, Godwin LS and Gardner JPA (2000) Jumping ship: a stepping stone event mediating transfer of non-indigenous via a potentially unsuitable environment. Biological Invasions 2(1), 75–79

Aquenal (2002) Final Report: Exotic Marine Pest Survey: Port of Hobart, Tasmania. Report prepared for Hobart Ports Corporation Pty Ltd to meet the requirements of the AQIS Decision Support System (DSS) for Ballast Water Management, December 20, 2002, 159 p

Barnes H and Barnes M (1957) resistance to desiccation in intertidal barnacles. Science 126: 358

Barnes H, Finlayson DM and Piatigorsky J (1963) The effect of desiccation and anaerobic conditions on the behaviour, survival and general metabolism of three common cirripedes. Journal of Animal Ecology 32: 233–253

Barnes DKA (2002) Invasions of Marine life on plastic debris. Nature 416: 808–809

Barnes DKA and Fraser KPP (2003) Rafting by five phyla on man-made flotsam, in the Southern Ocean. Marine Ecology Progress Series 262: 289–291

Barnes DKA and Milner P (2005) Drifting plastic and its consequence for sessile organism dispersal in the Atlantic Ocean. Marine Biology 146: 815–825

Castro JM, Lopez DA and Vial MV (2001) Physiological responces to hypoxia and anoxia in *Jehlius cirratus* (Darwin, 1854) (Cirripedia, Chthamalidae) in the upper intertidal zone. Crustaceana 74(2), 161–170

Cawthorne DF and Davenport J (1980) The effects of fluctuating temperature, salinity and aerial exposure upon larval release in *Balanus balanoides* and *Elminius modestus*. Journal of the Marine Biological Association of the United Kingdom 60: 367–377

Coleman N (1973) Water loss from aerially exposed mussels. Journal of Experimental Marine Biology and Ecology 12: 145–155

Crisp DJ (1968) The spread of *Elminius modestus* Darwin in north–west Europe. Journal of the Marine Biological Association of the United Kingdom 37: 483–520

Davenport J and Irwin S (2003) Hypoxic life of intertidal barnacles. Marine Biology 143: 555–563

Frenot Y, Chown SL, Whinam J, Selkirk PM, Convey P, Skotnicki M and Bergestrom DM (2005) Biological invasions in the Antarctic: extent, impacts and implications. Biological Reviews 80: 45–72

Garnham J (1998) Distribution and impact of *Asterias amurensis* in Victoria. In: Goggin CL (ed) Proceedings of a meeting on the biology and management of the introduced seastar *Asterias amurensis* in Australian waters, 19 May 1998. Centre for Research on Introduced Marine Pests Technical Report, Hobart, Tasmania, Australia 15: 18–21

Gower JC (1971) A general coefficient of similarity and some of its properties. Biometrics 27: 857–874

Greenaway P (2003) Terrestrial adaptations in the Anomura (Crustacea: Deacapoda). Memoirs of the Museum Victoria 60(1), 13–26

Guerra-Garcia JM and Takeuchi I (2004) The Caprellidea (Crustacea: Amphipoda) from Tasmania. Journal of Natural History 38: 967–1044

Hays KR and Hewitt CL (1998) Risk assessment framework for ballast water introductions. Centre for Research on Introduced Marine Pests Technical Report No. 14. CSIRO Marine Research, Hobart, Australia, 116 p

Hays KR and Hewitt CL (2000a) Risk assessment framework for ballast water introductions – volume II. Centre for Research on Introduced Marine Pests Technical Report No. 21. CSIRO Marine Research, Hobart, Australia, 188 p

Hays KR and Hewitt CL (2000b) Quantitative biological risk assessment of the ballast water vector: an Australian approach. In: Pederson J (ed) Marine Bioinvasions: Proceedings of the First National Conference, January 24–27, Massachussetts Institute of Technology, Sea-Grant Program, Boston MA: 370–386

Hewitt CL and Hays KR (2002) Risk assessment of marine biological invasions.. In: Leppakoski E, Gollasch S and Olenin S (eds) Invasive Aquatic Species of Europe: Distribution, Impacts and Management, pp 583–. Kluwer Academic Publishers, Dordrecht, The Netherlands,

Hilliard RW and Raaymakers S (1997) Ballast water risk assessment for twelve warm-water ports in Queensland, Australia. Proceedings of the 13th Australasian Coastal and Ocean Engineering Conference and the 6th Australasian Port and Harbour Conference, Christchurch, New Zealand, 7–11 September 1997: 717–723

Jones MB and Greenwood JG (1982) Water loss of a porcelain crab, *Petrolisthes elongates* (Milne Edwards, 1837) (Decapoda, Anomura) during atmospheric exposure. Comparative Biochemistry and Physiology A 72(4), 631–636

Kennedy VS (1976) Desiccation, higher temperatures and upper intertidal limits of three species of sea mussels (Mollusca: Bivalvia) in New Zealand. Marine Biology 35: 127–137

Keough MJ and Ross DJ (1999) Introduced fouling species in Port Phillip Bay. In: Hewitt CL, Campbell ML, Thresher RE and Martin RB (eds) The Introduced Species of Port Phillip Bay, Victoria. Centre for Research on Introduced Marine Pests Technical Report No. 20. CSIRO Marine Research, Hobart, pp 193–226

Kerry K, Riddle M and Clarke J (1999) Diseases in Antarctic Wildlife. A report for The Scientific Committee on Antarctic Research (SCAR) and the Council of Managers of National Antarctic Programs (COMNAP), 104 p

Lewis PN, Hewitt CL, Riddle M and McMinn A (2003) Marine introductions in the Southern Ocean: an unrecognized hazard to biodiversity. Marine Pollution Bulletin 46: 213–223

Lewis PN, Riddle MJ and Smith SDA (2005a) Assisted passage or passive drift: a comparison of alternative transport mechanisms for non-indigenous marine organisms into the Southern Ocean. Antarctic Science 17(2), (in press)

Lewis PN, Riddle MJ and Hewitt CL (2005b) Management of exogenous threats to Antarctica and the sub-Antarctic islands: balancing risks from TBT and non-indigenous marine organisms. Marine Pollution Bulletin 49: 999–1005

McEnnulty FR, Jones TE and Bax NJ (2001) The Web-Based Rapid Response Toolbox. Web publication: < http://crimp.marine.csiro.au/NIMPIS/controls.htm >. Date of release: June 2001, Date of access: 19/11/2004

Poore GCB and Storey M (1999) Soft sediment Crustacea of Port Phillip Bay. In: Hewitt CL, Campbell ML, Thresher RE and Martin RB (eds) The Introduced Species of Port Phillip Bay, Victoria. Centre for Research on Introduced Marine Pests Technical Report No. 20. CSIRO Marine Research, Hobart. pp 150–170

Stewart Grant W and Cherry MI (1985) *Mytilus galloprovincialis* Lmk. in Southern Africa. Journal of Experimental Marine Biology and Ecology: 90(2), 179–191

Watson JE (1999) Review of hydroids introduced to Victorian waters. In: Hewitt CL, Campbell ML, Thresher RE and Martin RB (eds) The Introduced Species of Port Phillip Bay, Victoria. Centre for Research on Introduced Marine Pests Technical Report No. 20. CSIRO Marine Research, Hobart, pp 88–107

Whinam J, Chilcott N and Bergestrom DM (2005) Subantarctic hitchhikers: expeditioners as vectors for the introduction of alien organisms. Biological Conservation 121: 207–219